Vertical zonation of bioturbation and mass movements in the Portimão Bank (Gulf of Cadiz, SW Iberia)

Zonación vertical de la bioturbación y movimientos en masa en el Banco de Portimão (Golfo de Cádiz, SO de Iberia)

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Abstract: This work presents results from bioturbation intensity and trace fossil analysis of the piston core PC07, recovered at Portimão Bank during the MONTERA cruise in 2012. The aim was to investigate the potential of bioturbation analysis as an indicator for mass movement events. Bioturbation and trace fossil identification was complemented with results from sedimentological analysis (grain-size, carbonates, organic matter), measurements of magnetic fabric parameters (mass magnetic susceptibility and anisotropy of magnetic susceptibility), and AMS 14C dating. Considering the vertical zonation of bioturbation, magnetic fabric changes, sedimentology and AMS radiocarbon dating, two intervals were identified, Interval A (0-180 cm) and Interval B (180-356 cm), being the limit between them placed at 180-181cm. These intervals seem to replicate almost the same vertical zonation of bioturbation and the trend of carbonates and organic matter changes downcore. The magnetic fabric parameters (degree of anisotropy – Pj and shape – T of the magnetic susceptibility ellipsoid) show the major change at about 180 cm. Geochronological results indicate that the age of sediments in Interval A is 8590 yr BP (31-32 cm) and 14 300 yr BP (103-104 cm). Otherwise, ages in Interval B are the following: 5035 yr BP (181-182 cm), 8900±50 yr BP (219-220 cm), 18999±120 yr BP (303-305 cm). These results point to the emplacement of sediments of Interval A on top of youngest sediments of Interval due to landsliding. Since no internal deformation is seen, probably this indicates translational movement and short transport from the source.

Keywords: *bioturbation, magnetic fabric, landslide, Portimão Bank, Gulf of Cadiz*

1. INTRODUCTION

Little is known about the relationship between bioturbation intensity and the occurrence of mass movement events. Few works have been published addressing the behavior of soft bottom benthic communities after sudden events, such as storms, river discharges, volcanic eruptions, turbidites and landslides (e.g. Okey, 1997; Galeotti *et al*., 2002; Miller *et al*., 2009; Botterill *et al*., 2014). The impact of landslides and slumps on those communities seems to be destructive, reducing infauna abundance and diversity. This was the scenario following the slump event in the Monterey Canyon (California, USA) triggered by the Loma Prieta earthquake in 1989 (Okey, 1997). In this case, infaunal abundances were much lower in the slumped areas, whereas being recolonized by opportunist worm species that then declined rapidly (Okey, 1997). The record of declination and recovery of past macrofaunal benthic communities following destructive events has been established by bioturbation and trace fossil analysis (e.g. Rodríguez-Tovar *et al*., 2004). Considering the scale of the geological record, the occurrence of the cited catastrophic events has been far more common, in particular in seismogenic settings where landslides can be triggered. This work presents the preliminary results of the conjugated analysis of the bioturbation record, sedimentological and magnetic fabric data of a piston core at Portimão Bank (Gulf of Cadiz). The aim of the work is to investigate the potential of bioturbation analysis as an indicator for mass movement events.

2. DATA AND METHODS

This work is based on the multidisciplinary analysis of the piston core PC07 recovered from the southern flank of the Portimão Bank at 2876 m water depth during the MONTERA Cruise in 2012 (Fig. 1). The total core length is 356 cm.

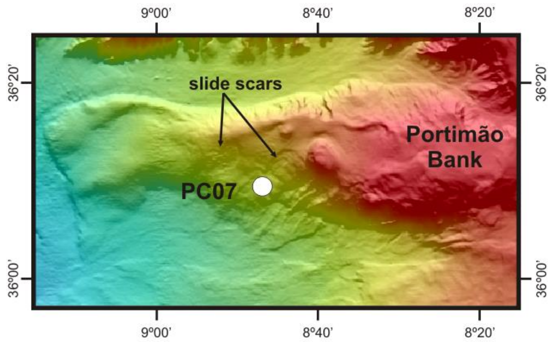

Fig. 1. Location of the piston core PC07 retrieved from the southern flank of the Portimão Bank, nearby the foot of a slide scar.

After detailed visual core description, several techniques were used to analyze sediment properties as magnetic fabric parameters, grain-size distribution, carbonate and organic matter content. Mass magnetic susceptibility and anisotropy of magnetic susceptibility were measured each 2.0 cm on MFK1-FA in a total of 167 samples. Grain-size analyses were performed on 73 samples using a Beckman Coulter LS laser. The organic matter (OM) was determined by loss of weight on ignition (LOI) by heating 200 mg of dry sediment in a furnace at 450ºC for two hours. Carbonate content was analysed in accordance with the method of Scheibler (ÖNORM L 1084, 1999) using an Eijkelkamp calcimeter. Identification of trace fossils was made by visual core inspection and digital photos analysis. The methodology proposed by Dorador *et al.* (2014) for enhancement of photos was also applied, providing a better way for trace fossil recognition and identification.

3. RESULTS

3.1 Vertical zonation of bioturbation

The record of bioturbation in the core PC07 can be divided in two distinct and large intervals, namely, Interval A from 0 cm to 180 cm and Interval B from 180 cm to 356 cm (base of the core). A vertical zonation regarding the bioturbation intensity and trace fossil is well recognized in both intervals. Three zones resulting from sediment reworking by biogenic activity are encountered, a mixing and mottled highly oxidized zone, a mottled zone with abundant trace fossil and an isolated burrows zone. This last zone grades downwards into a zone with slight or no bioturbation. This vertical zonation pattern seems to be almost equally replicated in the two intervals. In Interval A, a mixing zone extents from the top of the core down to 7 cm and is characterized by mottled bedding with bright orange color indicating highly oxidized sediment. Bioturbation index (BI) as defined by Taylor & Goldring (1993) is 5/6. From 7 cm to 75cm, oxidation decreases progressively downcore, mottled bedding is observed and BI is 5 to 4. No clear trace fossil is identify, although fainted icnogenera *Planolites* and *Thalassinoides* seems to occur at 27 cm. An unspecific isolated vertical burrow, lighter than the surrounding sediment, is seen between 7 and 27 cm. Below 75 cm until 181cm, the sediment is darker, massive, showing alternating light and dark bands at 124 –133 cm and 158 –165 cm. No trace of biogenic activity is identified (BI=0/1), except an isolated vertical burrow extending from 117cm upwards to 95cm. This trace fossil could be *Diplocraterion*. In Interval B (181-345 cm), a mixed and highly oxidized zone similar to the one described for Interval A is seen between 181 and 186 cm. BI is 5 or 6. From 186 cm to 219 cm a mottled and oxidized zone is recognized. Trace fossil are abundant and represented by *Planolites* and probably *Thalassinoides*. The zone between 219 cm and 264 cm is characterized by darker sediment indicating more anoxic conditions and by the decrease of trace fossils abundance (BI = 3). Isolated *Planolites* and several *Zoophycos* are seen (Fig. 2). Dark spots of pyrite are also observed. From 264 cm until the end of the core, bioturbation is unclear, except for the presence of a vertical pyritized burrow between 267 and 303 cm. Below 303 cm the sediment seems to be almost undisturbed (BI = 1). Interval A and Interval B are separated by an inclined surface (<20º) of black color.

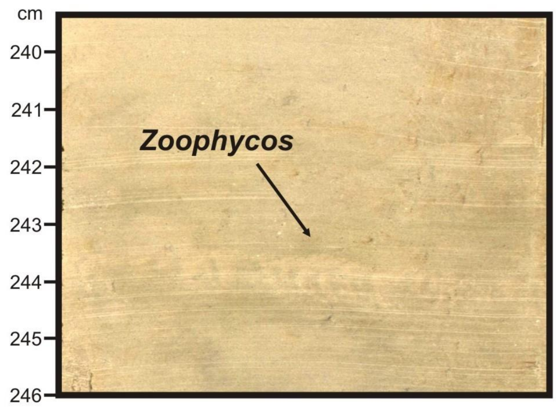

Fig. 2. Example of the trace fossil Zoophycos crosscut by diagenetic laminations <1mm thick.

3.2 Sedimentological and magnetic parameters analysis

Sediments of PC07 are characterized by a very low content in sand (0-6%) and are predominantly constituted by silt (42-50%) and clay (38-57%) (Fig. 3).

The mean grain-size has an average of 4.13 µm, allowing the sediments classification as silt and very fine silt. This last type is located in the intervals 0-55 cm and 179-236 cm, and the fine silt between 72-175 cm and 241-346 cm. In particular, the highest clay content is recorded in the 179-236 cm interval. Regarding the carbonate measurements, the values decrease from 0 to 111 cm, recording an increase from this level until 294 cm. The highest carbonate values occur at 16 cm (32.52%) and 208 cm (35.05%), coinciding with the base of the more oxidized zone, respectively, in Intervals A and B (Fig. 3). Organic matter measurements show that the highest values, in general >10%, occur below 183 cm. Conversely, the lowest values, in general <10%, are found above this level, except at 125, 129, 133, and 137 cm.

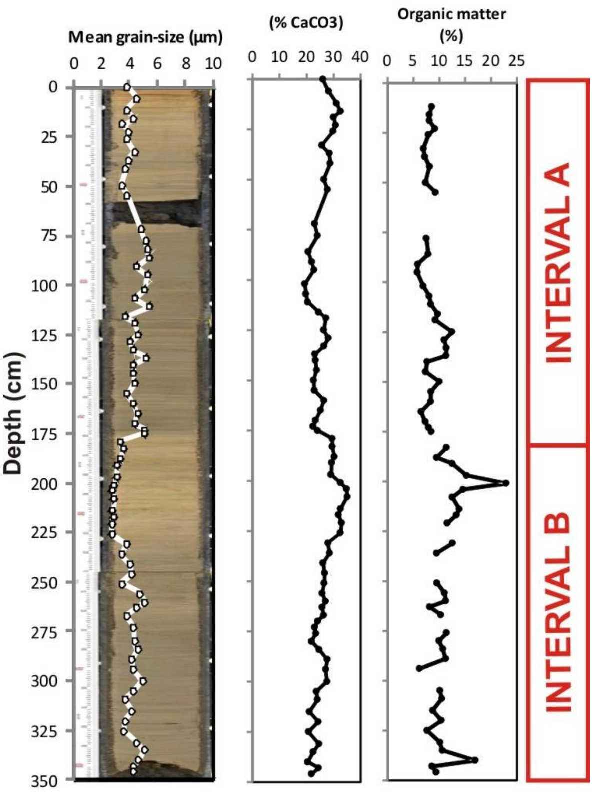

Fig. 3. Digital photo of core PC07 with grain-size, carbonate and organic matter measurements.

Regarding the magnetic fabric parameters (degree of anisotropy – Pj and shape – T of the magnetic susceptibility ellipsoid), the major change is recorded at about 180 cm (Fig. 4). From top of the core to approximately 175 cm it is observed a dominant oblate shape and regular increase of Pj from 1.02 to 1.10. Below, until 270 cm, it is observed a fast drop of Pj accompanied by a change of the magnetic susceptibility ellipsoid shape, from oblate to neutral or even prolate (Fig. 4). These changes correlate well with the beginning of Interval B at 180 cm.

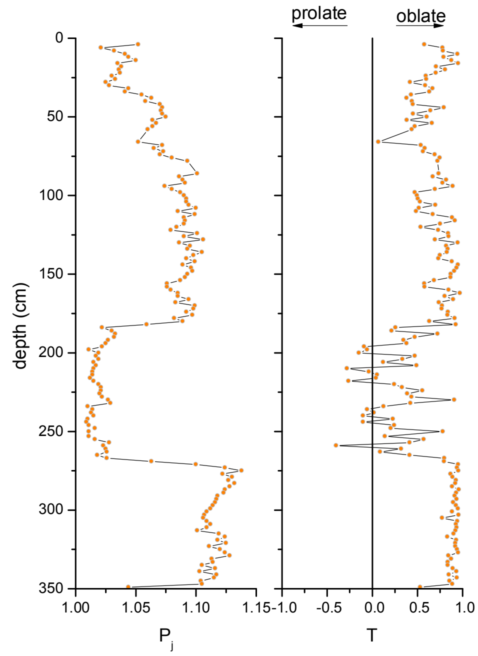

Fig. 4. Evolution in depth of T - shape of the magnetic susceptibility ellipsoid and Pj – corrected degree of anisotropy.

3.3 AMS 14C dating

Geochronological results indicate that the conventional radiocarbon ages of sediments in Interval A are 8590 yr BP (31-32 cm) and 14 300 yr BP (103-104 cm). In Interval B obtained conventional radiocarbon ages are as following: 5035 yr BP (181-182 cm), 8900±50 yr BP (219-220 cm) and 18999±120 yr BP (303-305 cm).

4. DISCUSSION AND CONCLUSIONS

Considering the results obtained from sedimentological, magnetic fabric and bioturbation analysis complemented by AMS 14C dating, it seems that Interval A and Interval B correspond to distinct sedimentary sequences with a boundary located around 180 cm. The vertical zonation of bioturbation seems to be almost replicated in both intervals (Fig. 5). While bioturbation shows a similar pattern and trace fossil in both Intervals that can be interpreted as a typical zonation, two main aspects can be stressed: i) the presence in Interval A of an isolated vertical burrow at 7-27 cm and another at 95-117 cm, which could indicate escape behavior of the dwelling organism; ii) the absence of *Zoophycos* in deeper levels of Interval A, and its occurrence at expected levels in Interval B. Since *Zoophycos* producers are slow colonizers and prefer stable conditions, their presence suggest long periods with little disturbance, while their absence could indicate that this part of Interval B was not affected by mass movements.

Fig. 5. Part of Intervals A and B of core PC07 put side by side. Boundary between them is the inclined dark layer at ~180-181 cm. Red rectangles indicate the AMS 14C dating of layers (years BP). Yellow line indicates limits between different zones defined by bioturbation intensity, trace fossil and oxidation degree. Vertical scale is in cm.

As aforementioned, both intervals show progression of AMS ages but with superposition of them. This necessarily implies that at least one of the intervals is not *in situ*. Considering the remarks made above about the presence of trace fossils, and the fact that core PC07 was retrieved near the foot of a slide scar (Fig. 1), we suggest that Interval A results from mass movement event on the slope of the Portimão Bank. Moreover, the 180 cm marks a limit between distinct types of magnetic fabric. Above, the fabric is typically sedimentary (sub-horizontal foliation with oblate shape). Below, the mean magnetic lineation rotates 90º in turns of a vertical axis and the magnetic foliation departs from subhorizontal to oblique. This suggest that interval 180 – 250 cm, somehow is accommodating a non-sedimentary fabric but one related with accommodation of deformation. Since no internal deformation (e.g. slumps folds) is identified in this Interval, it could indicate that movement was probably translational and the landslide deposit suffered a short transport from its source. The inspection of multibeam bathymetry shows several slide scars located nearby the site where core PC07 was taken, enforcing the interpretation that the Interval A corresponds to a landslide deposit emplaced soon after 5035 yr BP, nearby its source without important transportation. Variations of bioturbation zonation and intensity along a core of marine sediments seem to be a good indicator for the occurrence of mass movements. However, this information needs to be complemented with other analysis to reinforce interpretations. The conjugation between bioturbation and trace fossil analysis with magnetic fabric parameters measurements, sedimentological analysis and AMS 14C dating appears to be a robust set of methods for the identification of mass movements.

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